

UNCLASSIFIED

AD NUMBER

ADB009533

LIMITATION CHANGES

TO:

Approved for public release; distribution is unlimited.

FROM:

Distribution authorized to U.S. Gov't. agencies only; Administrative/Operational Use; AUG 1970. Other requests shall be referred to Air Force Geophysics Lab., Hanscom AFB, MA 01731.

AUTHORITY

AEDC ltr 2 Aug 1976

THIS PAGE IS UNCLASSIFIED

THIS REPORT HAS BEEN DELIMITED
AND CLEARED FOR PUBLIC RELEASE
UNDER DOD DIRECTIVE 5200.20 AND
NO RESTRICTIONS ARE IMPOSED UPON
ITS USE AND DISCLOSURE.

DISTRIBUTION STATEMENT A

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

2



AF Geoffrey, Inc.
attn: OPR-1
Baltimore, MD, MD
01731

See 1473

ARO, Inc.

REC'D
MAR 8 1976
A

also excluded
for re-check of TCA

AEROSPACE ENVIRONMENTAL FACILITY
ARNOLD ENGINEERING DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
ARNOLD AIR FORCE STATION, TENNESSEE

PROPERTY OF U S AIR FORCE
HEDC LIBRARY
F40600-71-C-0002

**CALIBRATION OF A FIRST-GENERATION
CIRCULAR VARIABLE FILTER SPECTROMETER**

**R. M. Warner
ARO, Inc.**

This document may be further distributed by any holder only with specific prior approval of Air Force Cambridge Research Laboratory (CROR), L. G. Hanscom Field, Bedford, Massachusetts 01730 and Arnold Engineering Development Center (AETS), Arnold Air Force Station, Tennessee 37389.

ACCESSION TO	
DTIC	
SEC	
REF	
<i>Put in file</i>	
<i>B</i>	

FOREWORD

The work reported herein was sponsored by the Air Force Cambridge Research Laboratories (AFCRL)(CROR), Bedford, Massachusetts, under Program Element 62301D, Project 8692.

The results presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), Arnold Air Force Station, Tennessee, under Contract F40600-71-C-0002. This work was conducted from January 13 to April 17, 1970, under ARO Project No. SA0043. The manuscript was submitted for publication on April 28, 1970.

On July 1, 1970, the Aerospace Environmental Facility, ARO, Inc., became the Aerospace Division of the von Kármán Gas Dynamics Facility, ARO, Inc.

Information in this report is embargoed under the Department of State International Traffic in Arms Regulations. This report may be released to foreign governments by departments or agencies of the U. S. Government subject to approval of AFCRL (CROR) and AEDC (AETS), or higher authority within the Department of the Air Force. Private individuals or firms require a Department of State export license.

The technical report has been reviewed and is approved.

Robert T. Otto
Major, USAF
AF Representative, AEF
Directorate of Test

Roy R. Croy, Jr.
Colonel, USAF
Director of Test

ABSTRACT

To permit accurate evaluation of previous airborne measurements, the AFCRL first-generation circular variable filter (CVF) spectrometer was calibrated in the Aerospace Research Chamber (7V). Testing consisted of calibration and linearity checks, angular response measurements, off-axis rejection measurements, and modulation transfer function determination. The calibration measurements defined the spectral radiance responsivity over a 4.0- to 13.0-micron wavelength range and the noise-equivalent radiance (NER) of the instrument.

This document may be further distributed by any holder only with specific prior approval of Air Force Cambridge Research Laboratory (CROR), L. G. Hanscom Field, Bedford, Massachusetts 01730 and Arnold Engineering Development Center (AEDC), Arnold Air Force Station, Tennessee 37389.

CONTENTS

	<u>Page</u>
ABSTRACT	iii
NOMENCLATURE	vi
I. INTRODUCTION	1
II. APPARATUS	1
III. PROCEDURE	3
IV. RESULTS AND DISCUSSION	5
V. CONCLUSIONS	8

APPENDIXES

Figure

1. AFCRL First-Generation CVF Spectrometer Fitted with LN ₂ Cover Cap	11
2. Aerospace Research Chamber (7V)	12
3. Detector Temperature Monitor Voltage, V_D versus Temperature	13
4. DC Offset, V_o versus V_D	14
5. Variation in Detector Voltage, V_T , at 8.92 versus V_D	15
6. Radiance Correction Factor versus V_D	16
7. Spectral Responsivity versus Wavelength, Chamber Test No. 1	17
8. Detector Voltage versus Spectral Irradiance, Chamber Test 2, Run 1	18
9. Detector Voltage versus Spectral Irradiance, Chamber Test 2, Run 2	19
10. Detector Voltage versus Spectral Irradiance, Chamber Test 2, Run 3	20
11. Detector Voltage versus Spectral Irradiance, Chamber Test 2, Run 4	21
12. Detector Voltage versus Spectral Irradiance, Chamber Test 2, Runs 1 to 4 (Corrected for V_D)	22
13. Detector Voltage versus Spectral Irradiance, Chamber Test 2, Runs 1 to 4 (Not Corrected for V_D)	23
14. Preliminary Inverse Spectral Irradiance Responsivity versus Wavelength	24
15. Inverse Spectral Radiance Responsivity versus Wavelength	25
16. Spectral Noise Equivalent Radiance	26
17. Spectrometer Internally Generated Background Radiance	27
18. Detector Voltage versus Angular Position of Blackbody Source	28
19. Detector Voltage versus Angular Position of Earth Simulator Source	29

II. TABLE

I. Wavelength Calibration of AFCRL CVF Spectrometer	30
---	----

NOMENCLATURE

- V_D Detector temperature monitor voltage
- V_o DC offset voltage (detector response when wide and narrow metal strips of the circular variable filter pass in front of the detector)
- V_T Detector response voltage
- E_λ Spectral irradiance

SECTION I INTRODUCTION

Air Force Cambridge Research Laboratories (AFCRL) is directing the development of a spectrometer to further studies of the infrared emittance and reflections of the earth's upper atmosphere. The basic components of the instrument consist of a liquid-helium (LHe)-cooled, mercury-doped, germanium photoconductive detector and a rotating circular variable filter (CVF).

A first-generation instrument was calibrated at AFCRL a week before flight in October, 1969.¹ The calibration was performed using a liquid-nitrogen (LN₂)-cooled cover cap fitted with a small IRTRAN-6® window (Fig. 1, Appendix I) which viewed a standard source with a known spectral radiance. A warm window temperature (approximately 300°K) necessitated calibration at unity gain and resulted in low signal-to-window radiation levels. Plans to repeat the test prior to flight using a liquid-neon-cooled cap without the window were curtailed by an urgent launch schedule.

Since the response interval of the spectrometer was brief during flight, further verification of its calibration was essential to accurately evaluate the airborne measurements. Definition of the noise-equivalent radiance (NER) for the high and low gain amplifier configurations was particularly desirable. AFCRL decided that this effort could be best accomplished in the 20°K environment provided by the Aerospace Research Chamber (7V) (Fig. 2). Testing at AEDC consisted of calibration and linearity checks, angular response measurements, and modulation transfer function determination. This report summarizes the results of these postflight tests.

SECTION II APPARATUS

2.1 AEROSPACE RESEARCH CHAMBER (7V)

The Aerospace Research Chamber (7V) consists of four integrated systems which are used for testing long wavelength infrared (LWIR) sensors.

2.1.1 Chamber

The (7V) is a stainless steel, horizontal chamber 7 ft in diameter by 12 ft in length with access provided by a 7-ft-diam door on each end of the chamber. A 2-ft-diam by 6-ft-long cylinder has been installed in the east door. Equipped with an isolation valve, this antechamber permits the return of a test article (sensor) to ambient conditions while the main chamber and the LWIR simulator equipment remain at test pressure and temperature.

¹T. P. Condon. "Post Flight Calibration of the AFCRL CVF Radiometer." Air Force Cambridge Research Laboratories Report, February 1970.

A liquid-nitrogen-cooled shroud, approximately 74 in. in diameter and 12 ft long, lines the chamber and operates at approximately 77°K. Inside the liquid-nitrogen-cooled shroud is a gaseous-helium (GHe)-cooled liner which is maintained at 20°K. The helium-cooled liner is fabricated from extruded aluminum finned tube material and is 10 ft long with an inner diameter of approximately 66 in.

2.1.2 Pumping System

Evacuation of the chamber is accomplished by two 260-liter/sec turbomolecular pumps backed by a lobe-type blower which, in turn, is backed by a 140-cfm mechanical vacuum pump. This dry pumping system prevents sensor optical system contamination. Additional pumping in the form of cryopumping is provided by the liquid-nitrogen- and gaseous-helium-cooled liners. The large cryopumping capacity provides the low pressures (10^{-8} torr) at which most of the tests are performed.

2.1.3 Refrigeration System

The liquid nitrogen is supplied from a 13,000-gallon storage tank; the boil-off gas is reliquefied and returned to the tank. The gaseous helium may be supplied from one of two 4-kw refrigeration units or from a 1-kw unit. The liquid helium required for sensors under test is provided by an AEDC helium liquefier unit.

2.1.4 LWIR Target Simulator System

This system consists of a target or source simulator and a solar and earth radiation simulator. The target or source simulator has the following specifications:

Resolution	0.5 milliradians
Field of View	6 deg x 6 deg
Rate of Motion	0 to 1 deg per sec
Modulation Frequency	100 to 500 Hz
Target Temperature Range	Classified
Irradiance Range	Classified

Background and stray radiation is controlled with gaseous-helium-cooled baffles as required.

The solar and earth radiation simulator has the following performance specifications:

Beam Diameter	10 \pm 1/2 in.
Angular Displacement (Beam)	0 to 70 deg (in horizontal plane)
Decollimation Angle	\pm 3 deg maximum
Uniformity	\pm 10 deg
Irradiance (at Sensor)	
Solar	Total: 0.14 w/cm ² 8-14 μ m: 1.5×10^{-4} w/cm ²
Earth	Total: 5.6×10^{-4} w/cm ² 8-14 μ m: 2×10^{-5} w/cm ²

SECTION III PROCEDURE

Calibration testing of the CVF spectrometer included two bench tests and two chamber runs.

3.1 BENCH TEST NO. 1

Since the instrument had not been refurbished subsequent to its flight and recovery, it was initially bench tested to verify its operational performance. A primary objective of this initial run was to determine whether the original wavelength versus pulse-index-code calibration performed with a monochromator at AFCRL in October was still valid. A linear interpolation over the entire spectral scan was not applicable since the motor which drives the circular variable filter did not run at constant speed. Instead, ten pulses were generated by contacts on the filter holder so that an accurate wavelength determination could be made at twenty positions in the scan (rise and fall of each pulse).

After the spectrometer and liquid-nitrogen-cooled cover cap were cooled to operating temperature, it was irradiated by a 1573°K blackbody source placed at a distance sufficient to prevent saturation in unity gain. Detector response was measured using three narrow bandpass filters placed one at a time in front of the source; one filter actually would have sufficed to ascertain the magnitude of any CVF rotational shift which might have occurred since the preflight calibration.

3.2 BENCH TEST NO. 2

The second bench test was conducted using the liquid-nitrogen-cooled cover cap without the warm window. One purpose of this test was to simulate that portion of the rocket flight during which the cold cap covered the instrument aperture. Another was to determine the variation of responsivity as a function of the indicated detector temperature. A third was to study the behavior of the spectrometer DC offset voltage when the wide and narrow metal strips of the circular filter passed in front of the detector. The wide metal strip was used in conjunction with a zero reset circuit to reduce the instrument output to zero once during each spectral scan for the high gain channel during flight.

The spectrometer was cooled to operating temperature with the cover cap reaching a stable temperature of 101°K within 20 minutes after liquid-nitrogen flow was initiated. The detector reached a temperature of approximately 8°K approximately one hour after liquid-helium transfer was initiated; however, a back-fill of dry gaseous helium was required at that time to convectively cool the circular filter sufficiently to bring the detector out of saturation. See Fig. 3 for a plot of detector temperature monitor voltage (V_D) versus temperature. When the detector became unsaturated, data were recorded on both magnetic tape and an oscillograph. Spectral scans were recorded periodically as the detector cooled to approximately 5.5°K. Then a liquid-helium transfer was terminated and the detector was allowed to warm up to 12°K while spectral scans were made periodically. Liquid-helium transfer was initiated again and data were recorded as the detector cooled to 10°K. The final step was to terminate liquid-helium flow, allowing the instrument to warm up, and to record data until the detector went into saturation in all gain configurations.

3.3 CHAMBER TEST NO. 1

Major test objectives of the initial chamber run included: (1) checking the validity of the calibration performed at AFCRL (this required extrapolation from a 0.25-in.-diam warm window to the full cold instrument aperture) and (2) determining the spectral noise-equivalent radiance (NER) of the spectrometer in the high and low gain configuration.

The spectrometer was installed in the antechamber with its aperture inserted through an optically tight baffle in the liner end plate. The instrument baffles were not cooled to 20°K but were allowed to stabilize at whatever temperature they would reach under normal operating conditions, i.e., cooled only by the flow of liquid nitrogen to the instrument. The liner optical baffles were thermally insulated from instrument baffles and were to reach a much lower temperature than the spectrometer baffles so that they would not influence the detector response signal.

This chamber test was only partially successful as neither set of baffles attained a temperature as low as desired, and a valid check of the instrument internal noise could not be made. However, the run provided the first check on the absolute calibration of the spectrometer operating in low gain without the small warm window. Test results are presented in Section 4.3.

3.4 CHAMBER TEST NO. 2

The cooling lines on the liner end plate optical baffle were modified before this run to ensure that the baffles would be cooled to approximately 20°K. Test objectives included: (1) checking linearity of response, (2) defining absolute spectral response, (3) measuring instrument spectral NER, (4) determining normal field of view, (5) measuring frequency response, and (6) establishing rejection angle of far off-axis radiation.

The spectrometer was cooled to operating temperature and was allowed to stabilize with a fixed liquid-helium transfer rate to the instrument dewar. The detector temperature monitor voltage (V_D) stabilized at approximately 1.6 v. The first spectral scans were made with the target system blackbody source deenergized to obtain detector response with the instrument exposed to a 20°K background to accomplish test objective (3). The blackbody target source was then heated and four runs were made to accomplish objectives (1) and (2). The source consisted of a 0.086-in.-diam heated cavity with an accurately controlled temperature. Detector spectral response data were obtained at varying source temperatures. No attempt was made to maintain the detector temperature constant during the first three runs. However, detector temperature monitor voltage, V_D , was held between 1.18 and 1.19 v for Run 4. This was an attempt to simulate the conditions of the AFCRL calibration performed in October, 1969, when V_D was maintained at 1.20 v.

The source was then moved in azimuth from 1.75 deg right (facing the spectrometer) to 2.25 deg left in an attempt to accomplish objective (4). Next, the target source radiation was chopped at frequencies ranging from 4 to 78 Hz to accomplish objective (5). Finally, the earth simulation system was energized and the projected beam was rotated about the spectrometer aperture optical axis to determine the instrument rejection angle.

SECTION IV RESULTS AND DISCUSSION

4.1 BENCH TEST NO. 1

Table I (Appendix II) lists the results of the first bench test where the average shift in wavelength of the three wavelengths checked was used to define a new wavelength corresponding to each pulse index. The nonlinearity in the wavelength shifts of the corrected values can be attributed to nonuniform pulse durations and the varying speed of the filter wheel drive motor. The shifts in wavelength observed during the test in no case exceeded the spectral resolution element of the circular variable filter which varied from $0.18\ \mu\text{m}$ at a wavelength of $4\ \mu\text{m}$ to $0.49\ \mu\text{m}$ at a wavelength of $13\ \mu\text{m}$.

4.2 BENCH TEST NO. 2

The voltages recorded at the locations where the wide and narrow metal strips on the circular filter passed in front of the detector were so nearly the same that they were averaged and plotted versus the detector temperature monitor voltage, V_D , in Fig. 4. The data represent three cooling-heating cycles and present a consistent pattern except for the two points (in boxes) near $V_D = 0.9\ \text{v}$. These two points confirm the fact observed in previous tests that the V_D value at which the instrument comes out of saturation during the cooling portion of a cycle or goes into saturation during a heating portion of a cycle cannot be predicted on the basis of V_D alone. The overall behavior of the plot (Fig. 4) can be explained by the fact that the DC offset is controlled by the ratio of the resistance of a feedback resistor to the detector resistance, both of which change, independently, with temperature. At first, when the spectrometer is warm, the feedback resistance is much larger than the detector resistance, and a large saturation DC offset occurs. Eventually during the cooling process the detector temperature reaches a value (near 10°K) where the detector resistance increases rapidly and then becomes practically constant with decreasing temperature. This resistance history explains the sudden drop from saturation near $V_D = 0.9\ \text{v}$ to a minimum near $V_D = 1.05\ \text{v}$. At that point the resistance of the feedback resistor becomes dominant, causing a gradual increase in DC offset from a minimum of $0.85\ \text{v}$ near $V_D = 1.0\ \text{v}$ to approximately $2\ \text{v}$ near $V_D = 2.9\ \text{v}$. The slight fluctuations in the plot beyond $V_D = 1.1\ \text{v}$ may or may not be significant.

The next step in the analysis of the cold cover cap data was to read the detector voltage at a wavelength of $8.92\ \mu\text{m}$ where the maximum signal was recorded for those scans which were not saturated at any point. This response was presumably caused by radiation from the cold cap which remained at a temperature constant to within $\pm 1.0^\circ\text{K}$ during the entire test. It was observed that the voltage at $8.92\ \mu\text{m}$ increased more with V_D than did the DC offset. This was interpreted as an increase in detector sensitivity with decreasing temperature (increasing V_D). To study the effect, the DC offset was subtracted from the voltage read at $8.92\ \mu\text{m}$ for each scan and the resulting difference voltages plotted versus V_D (Fig. 5). The plot is somewhat erratic, particularly for voltage differences less than $0.5\ \text{v}$, but the overall trend is quite definite in that the detector response voltage is increased by a factor of 10 as V_D increases from 0.9 to $2.6\ \text{v}$.

Since both the original calibration at AFCRL and Chamber Run No. 4 were performed with $V_D \approx 1.20$ v, this value was selected for normalizing purposes. A plot of the resultant radiance correction factor versus V_D is given in Fig. 6. The factor is unity for $V_D = 1.2$ v but is less than unity for $V_D > 1.2$ because a lower radiance is required to produce the same detector response signal.

4.3 CHAMBER TEST NO. 1

Since both the spectrometer sun shield baffling and the chamber optical baffle only cooled to temperatures in the 180°K range, an accurate determination of the internally generated noise could not be made. However, the test provided calibration data for the instrument operating in the low gain mode without the small warm window.

The results of this initial test run are presented in Fig. 7. The AFCRL October calibration curve has also been plotted for comparison purposes. For the short wavelength half of the circular variable filter, from 3.8 to $7.2\ \mu\text{m}$, all points are within a factor of 2.5 of the results extrapolated from the October warm window test. At the long wavelength end, from 7.4 to $13\ \mu\text{m}$, the difference in the result of the two tests increases as wavelength increases. However, since the signal-to-baffle radiation level ratio for the chamber test and the signal-to-window radiation level ratio for the CRL calibration are both low in this longer wavelength range, the difference depicted by the curves may not be realistic.

4.4 CHAMBER TEST NO. 2

4.4.1 Linearity of Response

In evaluating the linearity of the spectrometer, it was desirable to choose a wavelength such that the maximum source operating temperature produced a full-scale detector response and the background with the source deenergized provided no significant signal. These conditions permit the instrument to be evaluated over its entire dynamic range. Previous AFCRL calibrations indicated that a wavelength of $6.0\ \mu\text{m}$ best fulfilled these conditions. The results of Run 1 are shown in Fig. 8 where the resultant detector response, V_T , is plotted versus the spectral irradiance, E_λ , at $6\text{-}\mu\text{m}$ wavelength for various source temperatures. Any slope other than 45° would indicate a nonlinear relationship between E_λ and V_T . The detector temperature monitor voltage, V_D , varied from 1.48 to 1.65 v during this run.

The results of Run 2 are given in Fig. 9 where the spread in the data is much greater than for Run 1. The detector temperature monitor also varied greater for Run 2 (from 1.65 to 2.18 v). The results of Run 3 are given in Fig. 10 where the data spread is also rather large, but the spread in V_D was only from 1.15 to 1.20 v.

The results of Run 4 are given in Fig. 11, which is probably the best run of the test, not only because the value V_D was maintained nearly constant at 1.18 to 1.19 v, but also because it was the quietest of the four runs. The earlier runs were plagued by a 0.5-v detector oscillating ripple on all spectral scans caused by the filter motor bearings becoming too cold and increasing the load on the power supply. This condition cleared just before the conclusion of Run 3.

Since it was desirable to normalize all response curves to that for $V_D = 1.20$ v as outlined in Section 4.2, the data for all four runs were corrected for detector temperature (Fig. 6) and are depicted in Fig. 12. This curve shows that all the calibration points fall within a factor of two with a responsivity of $2.5 \times 10^{-9} \text{ cm}^{-2} \text{ m}^{-1} \text{ v}^{-1}$ selected as the absolute response at a wavelength of $6 \mu\text{m}$ and the detector temperature monitor correction factor plotted in Fig. 6 applied.

In order to determine the effect of the correction factor, a composite of all data obtained in the four runs is plotted without correcting for detector temperature in Fig. 13. The random scatter of the data tend to justify the adjustment.

4.4.2 Absolute Spectral Response

A preliminary plot of inverse spectral irradiance responsivity versus wavelength which has been compiled from data obtained during Run 4 for a source temperature of 460°K is presented in Fig. 14. The value of V_D for this run was 1.19 v versus the normalizing value of 1.20 used to generate Fig. 12; the value of $3.5 \times 10^{-9} \text{ cm}^{-2} \text{ m}^{-1} \text{ v}^{-1}$ at $6 \mu\text{m}$ wavelengths is comparable to the $2.5 \times 10^{-9} \text{ cm}^{-2} \text{ m}^{-1} \text{ v}^{-1}$ value defined by Fig. 12. Since the latter is based on data obtained during four separate runs, the curve in Fig. 14 was normalized to this value at $6 \mu\text{m}$ to obtain the final spectral radiance responsivity curve in Fig. 15. The instrument effective field of view was 3.1×10^{-3} steradians (sr).

4.4.3 Spectral NER

The spectral noise-equivalent radiance (NER) of the instrument for low gain was determined with the blackbody source deenergized. A fixed noise voltage of 0.05 v was assumed for wavelengths shorter than $7 \mu\text{m}$ since the detector response did not deviate appreciably from the offset voltage. Significant differences were observed between V_T and V_o at approximately $8 \mu\text{m}$, and the maximum difference occurred near $12.5 \mu\text{m}$. The instrument NER has been defined as the product of the detector response voltage (less the offset) and the corresponding spectral radiance responsivity depicted in Fig. 15. The resultant low gain channel NER plot is shown in Fig. 16.

In the shorter wavelength range, the NER of the instrument caused by electronics noise is overshadowed by the magnitude of the offset voltage signal. However, at approximately $8 \mu\text{m}$ the effect of an internal radiation load begins to appear and becomes well established at 10 to $11 \mu\text{m}$. This is evidenced by Fig. 17 which compares the NER at the longer wavelengths with the radiance of 100°K and 108°K blackbodies.

The measured instrument baffle temperature during Chamber Run 2 was 101°K which indicates that the long wavelength NER is probably caused by the baffles and the inside of the aperture barrel in front of the lens. Although these surfaces are outside the 1.8-deg half-angle (3.1×10^{-3} sr) nominal field of view of the instrument, they do subtend a solid angle of 2π when viewed from the center of the lens (an effective solid angle of π sr). It is probable that the scattering qualities of the lens would allow 10^{-3} of this radiation to reach the detector. This would be equivalent to a source of approximately 101°K filling the nominal 3.1×10^{-3} sr field of view.

The high gain channel did not produce usable data above $6\text{ }\mu\text{m}$ where the radiation emitted by the instrument baffles was large enough to saturate the detector. In the $3.8\text{-}6.0\text{-}\mu\text{m}$ range the background noise levels internally generated by the instrument were sufficient to cause intermittent saturation. Hence, no NER was determined for the instrument for the high gain channel.

4.4.4 Field of View

The blackbody source could not be moved far enough in either azimuth or elevation to reduce the detector response to half the on-axis signal. The results shown in Fig. 18 indicate that the total field of view of the instrument is greater than 4 deg since at 4 deg the signal is still well above 50 percent of the peak value. The original 3.6-deg total-field-of-view value attributed to the instrument was measured in warm surroundings with a lead sulfide (PbS) detector instead of with the cooled germanium:mercury (Ge:Hg) detector.

4.4.5 Frequency Response

No significant change was noted in spectrometer response to radiation chopped at frequencies of 78 Hz or less.

4.4.6 Rejection Angle for Far Off-Axis Radiation

A plot of the detector response for far off-axis angle radiation is presented in Fig. 19. The data apply for a wavelength of $6\text{ }\mu\text{m}$ and were taken on the low gain channel. At this wavelength the internally generated background from warm surfaces should not account for any of the observed voltage signal. It will be noted that the detector did not become unsaturated until the beam was approximately 5 deg removed from being on axis. The results would have been more meaningful if unsaturated data could have been obtained on the axis so that the ratio of the detector response at each angle to the on-axis response could have been computed.

SECTION V CONCLUSIONS

The calibration tests of the first-generation circular variable filter spectrometer demonstrate that this initial model was an order-of-magnitude-type measuring device. The main reasons for a lack of precision are (a) the loose correlation between the detector temperature monitor voltage, V_D , and the detector responsivity; (b) the level of internally generated noise; (c) DC drift; (d) the radiation emitted by warm internal instrument surfaces, and (e) the lack of a standard internal chopped source.

The NER plot for the low gain channel defines the minimum level of the detector response signal which must be attained to assign credibility to the radiance derived from that voltage. However, the high gain channel could not be used to make useful measurements because of the internally generated high background noise levels of the instrument.

APPENDIXES
I. ILLUSTRATIONS
II. TABLE

A E D C
236-70

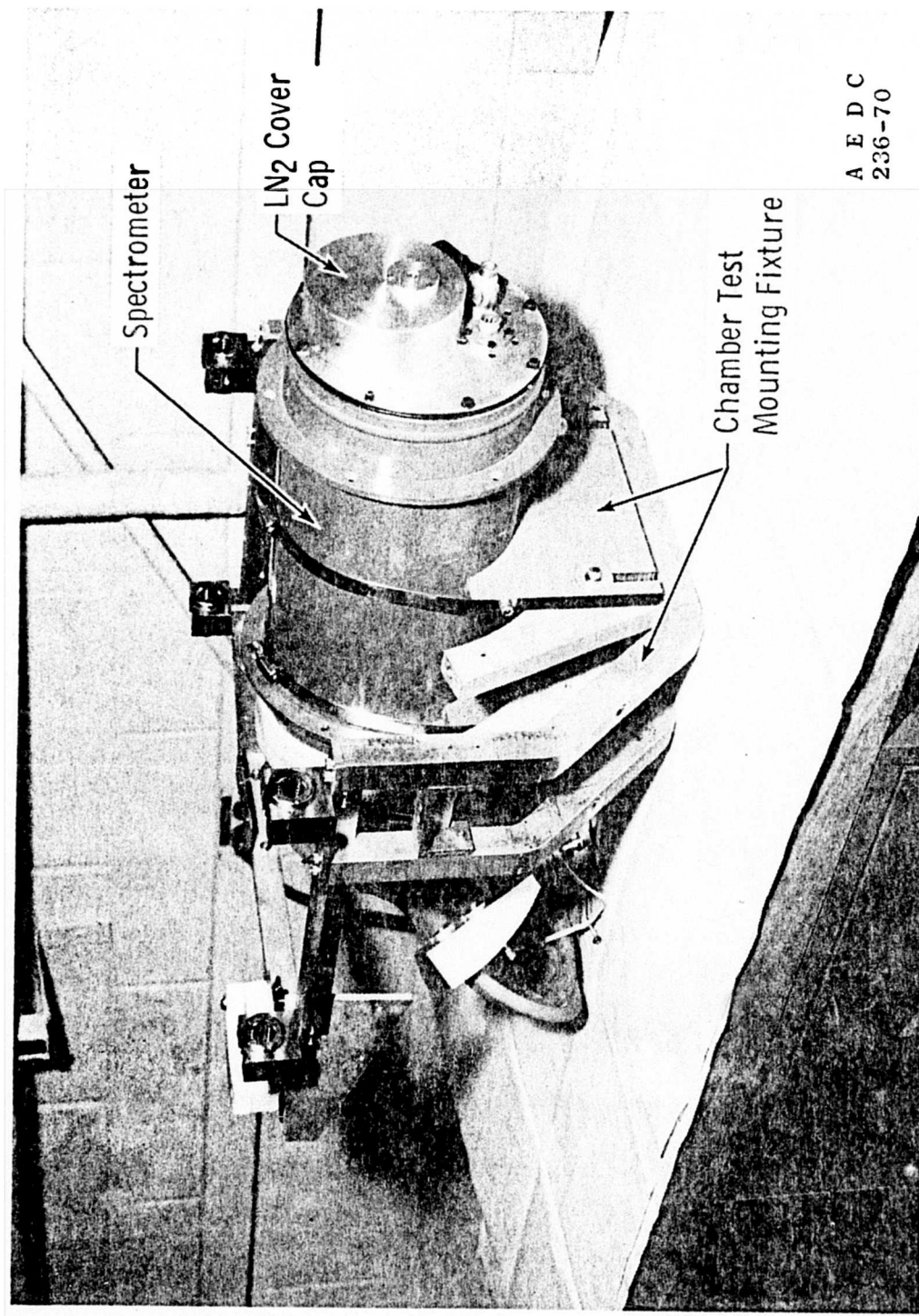


Fig. 1 AFCRL First-Generation CVF Spectrometer Fitted with LN₂ Cover Cap

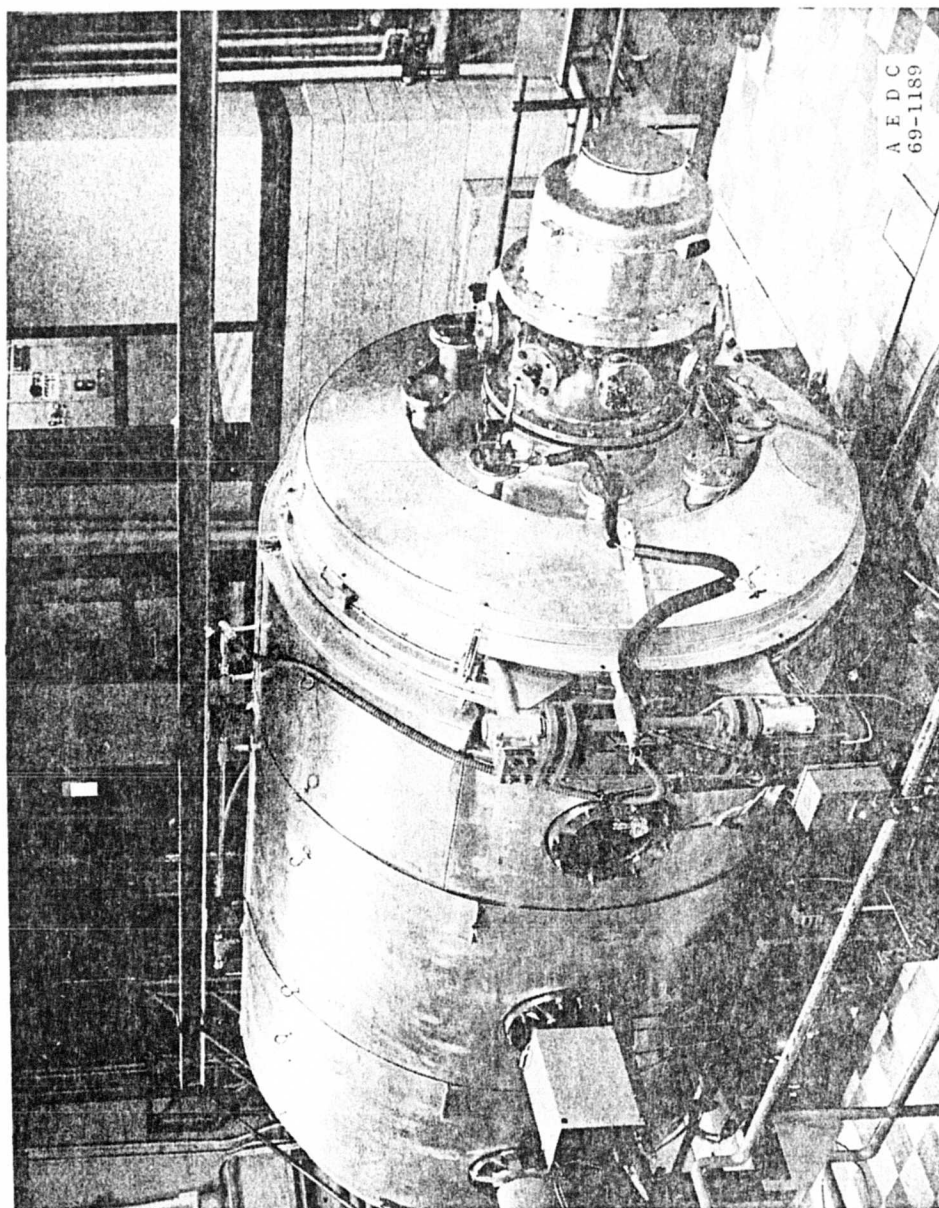
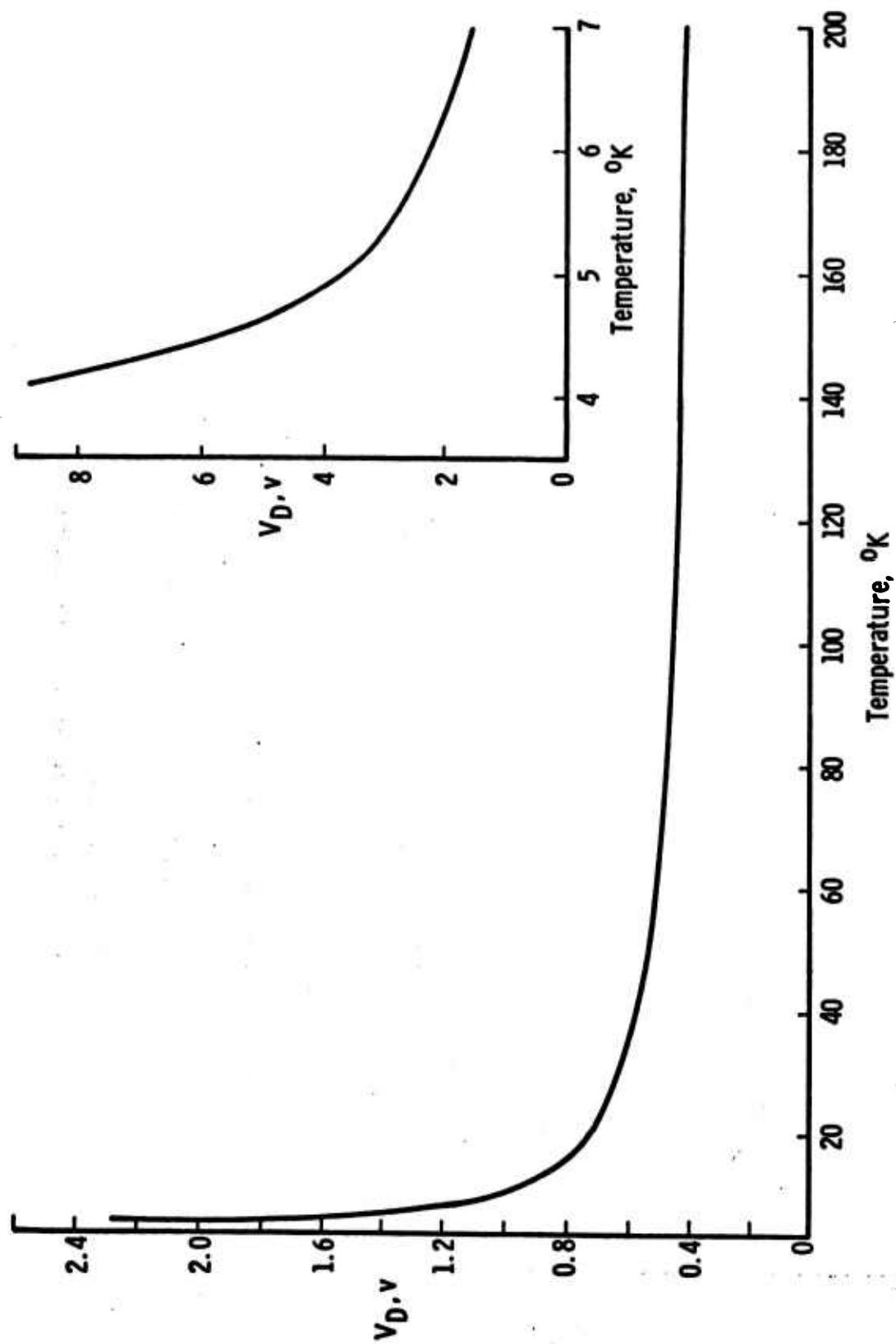
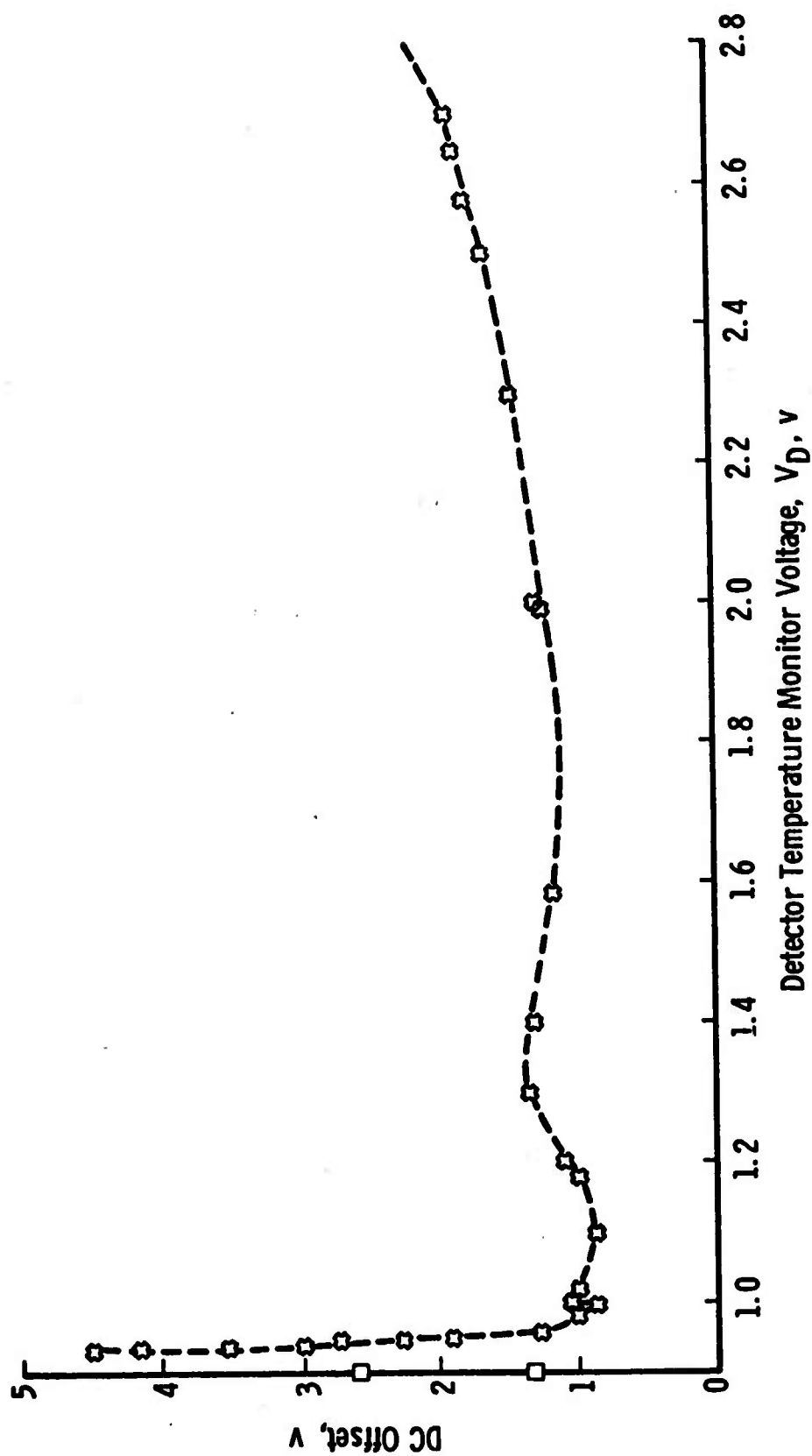


Fig. 2 Aerospace Research Chamber (7V)

Fig. 3 Detector Temperature Monitor Voltage, V_D , versus Temperature

Fig. 4 DC Offset, V_o , versus V_D

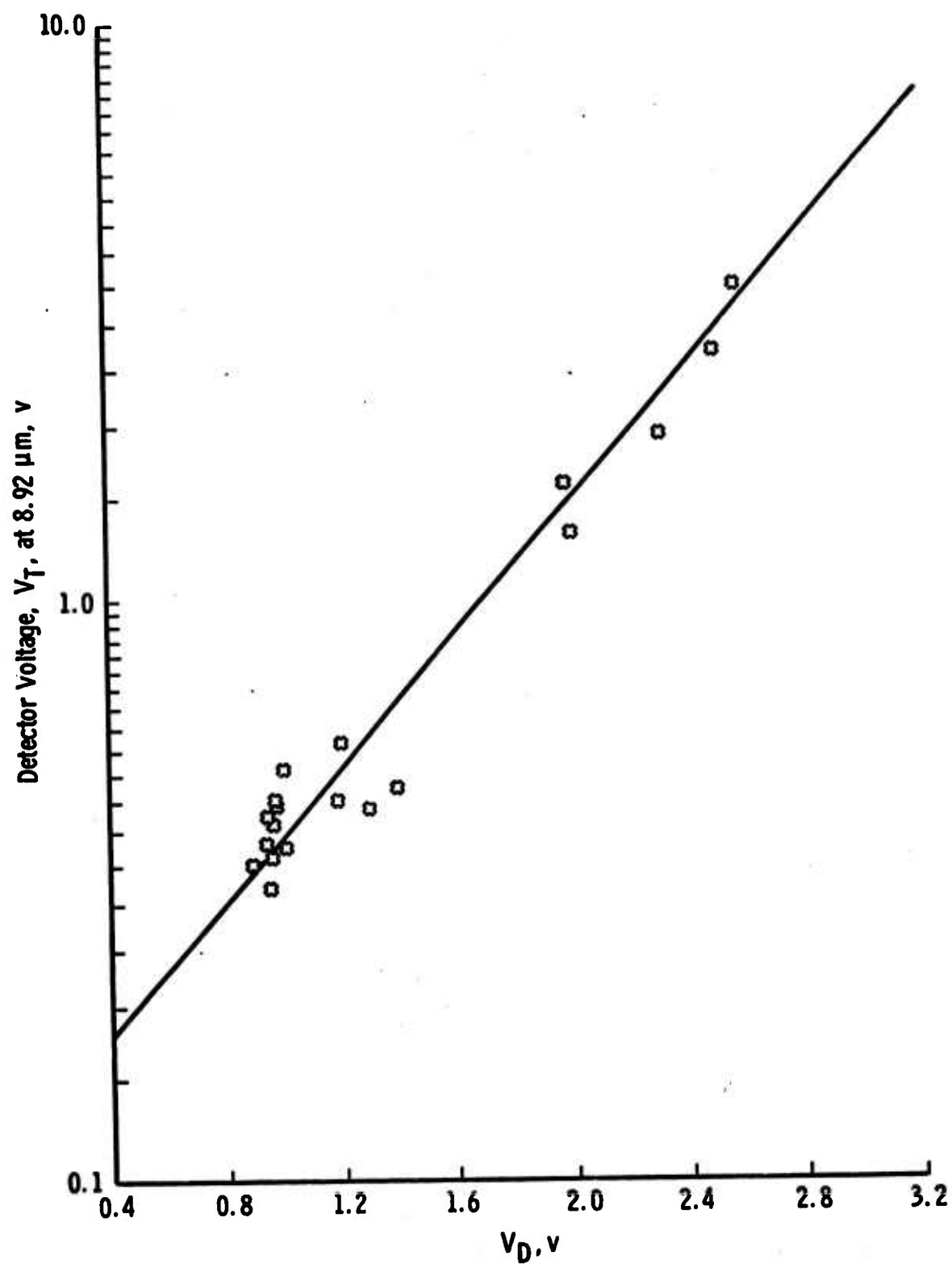


Fig. 5 Variation in Detector Voltage, V_T at 8.92 versus V_D

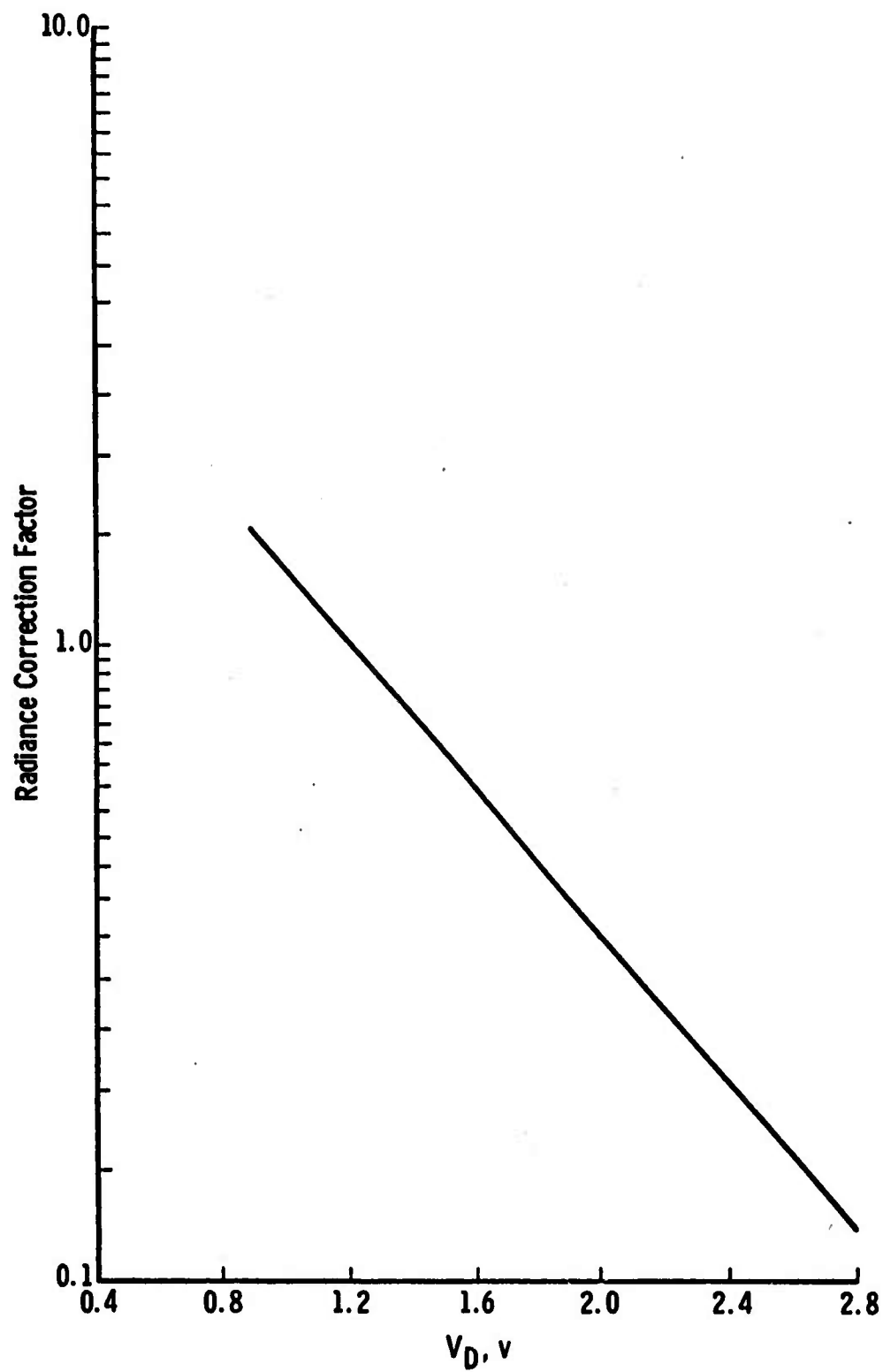


Fig. 6 Radiance Correction Factor versus V_D

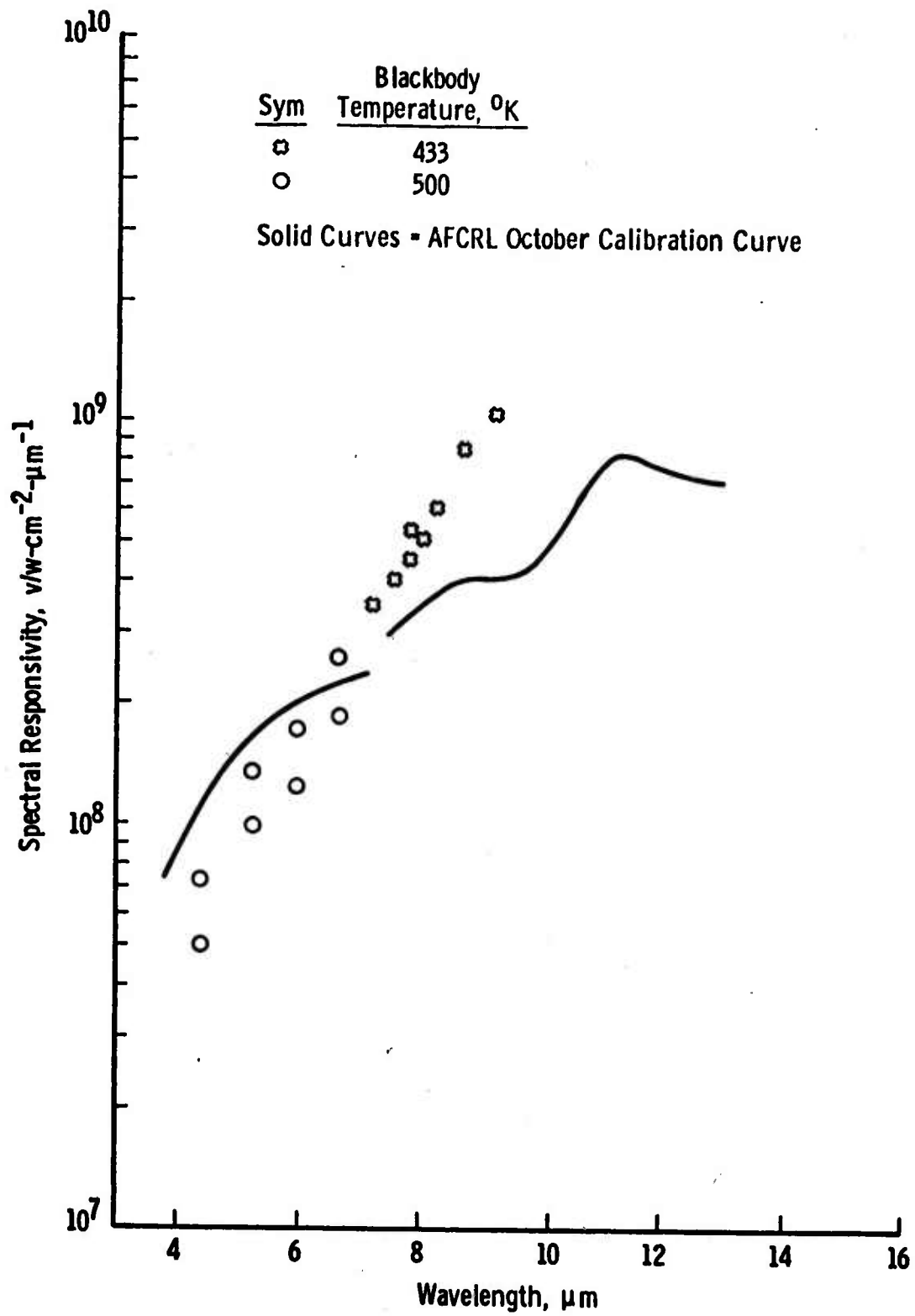


Fig. 7 Spectral Responsivity versus Wavelength, Chamber Test No. 1

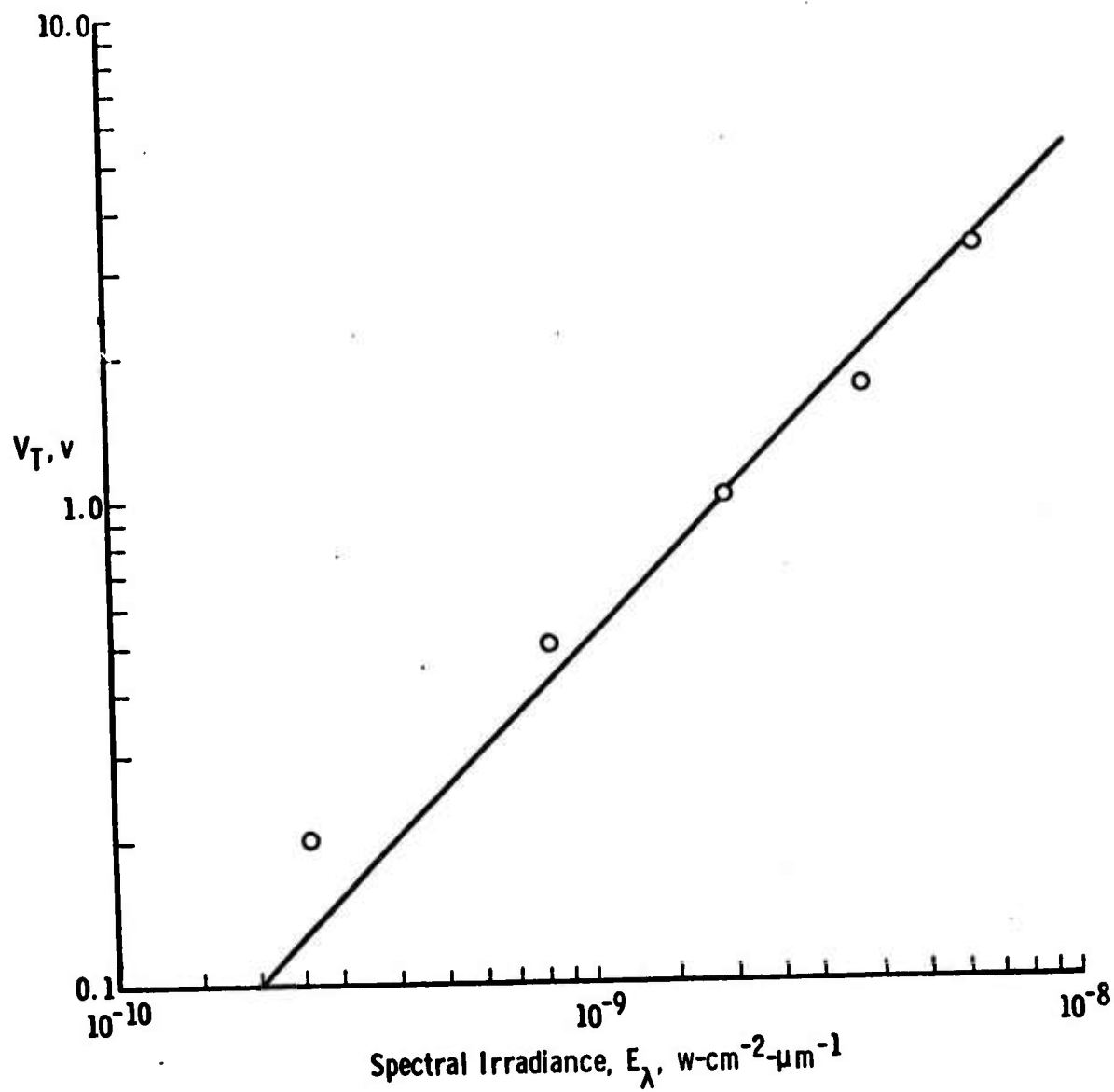


Fig. 8 Detector Voltage versus Spectral Irradiance, Chamber Test 2, Run 1

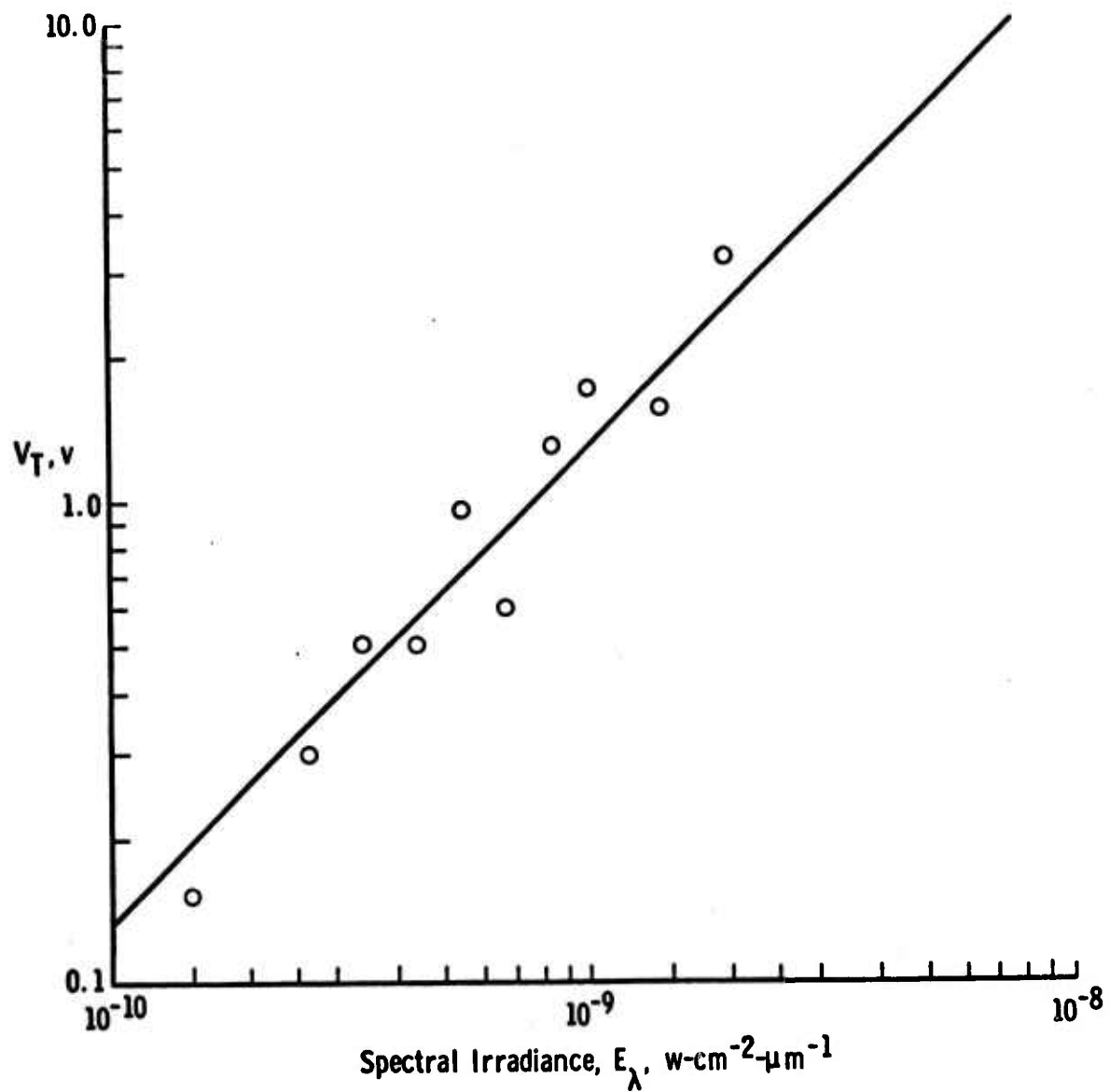


Fig. 9 Detector Voltage versus Spectral Irradiance, Chamber Test 2, Run 2

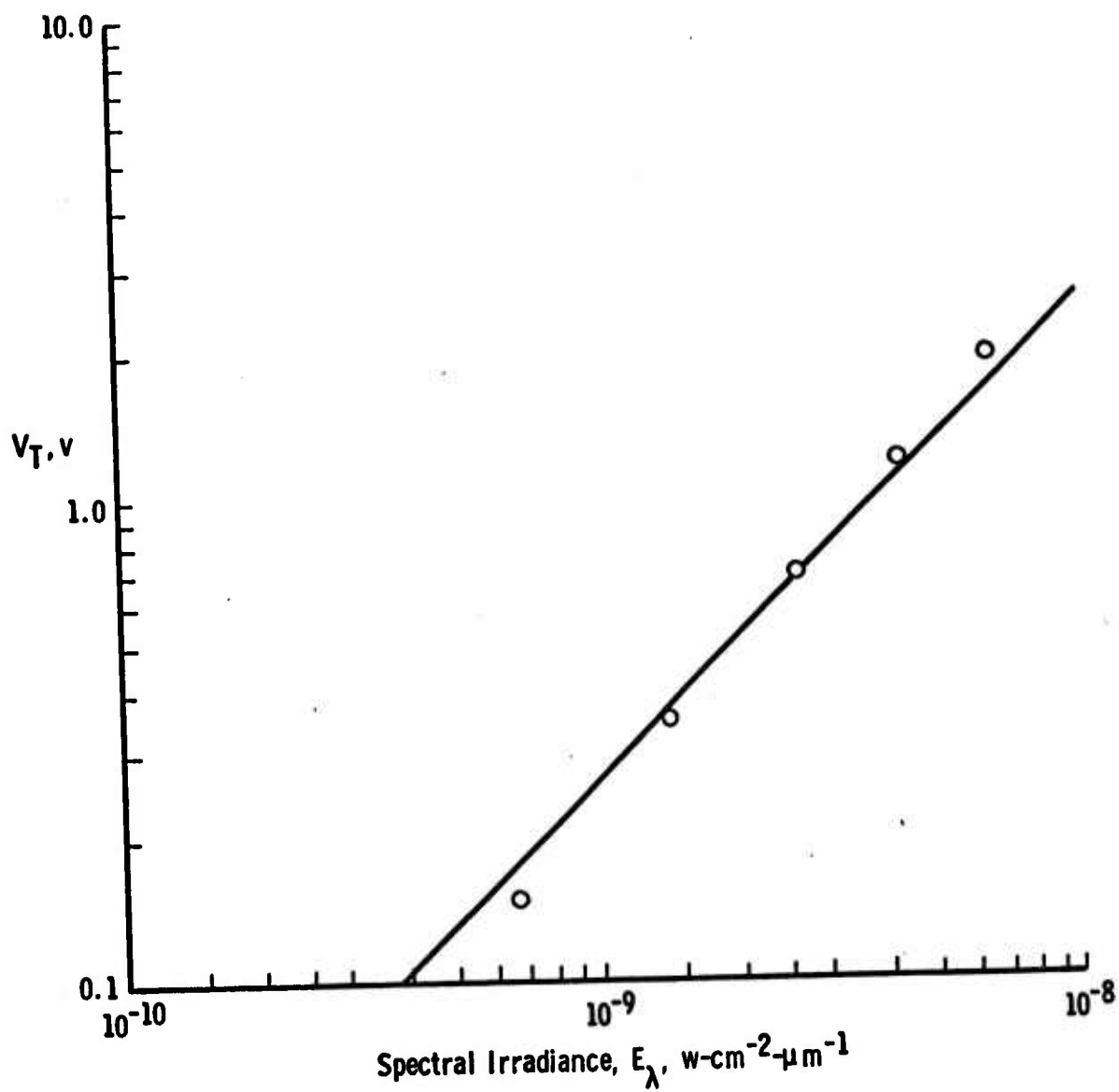


Fig. 11 Detector Voltage versus Spectral Irradiance, Chamber Test 2, Run 4

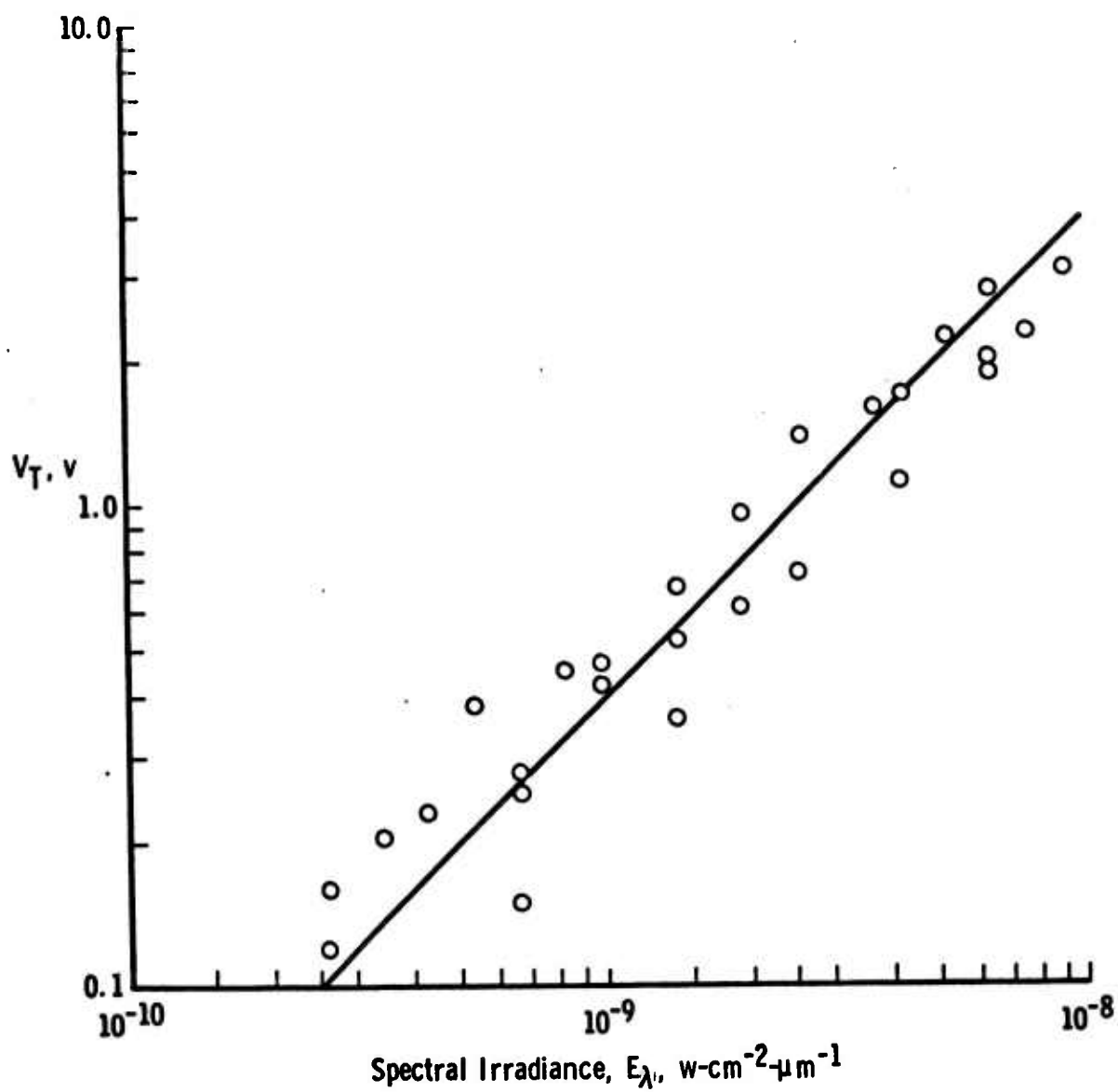


Fig. 12 Detector Voltage versus Spectral Irradiance, Chamber Test 2, Runs 1 to 4
(Corrected for V_D)

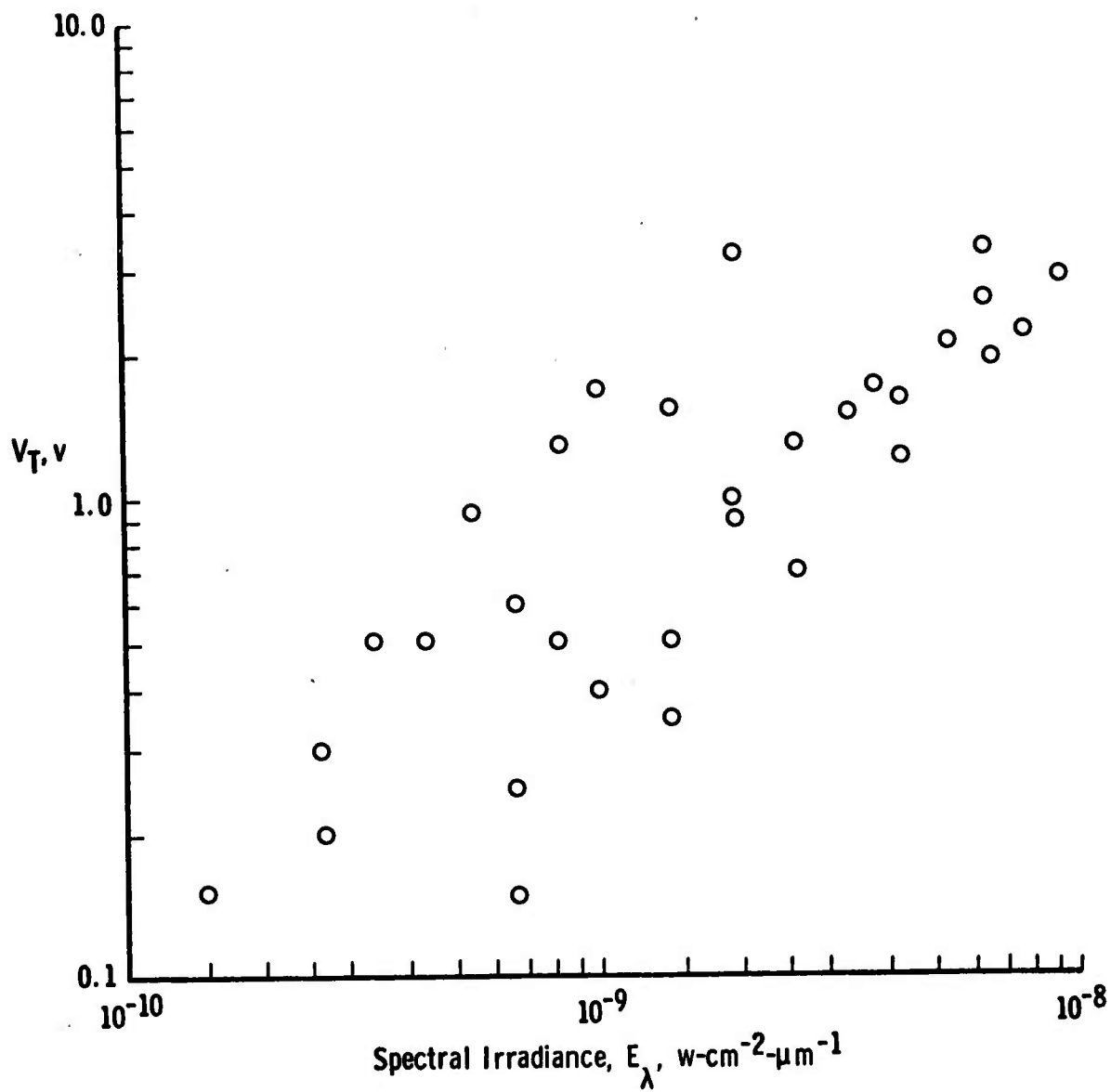


Fig. 13 Detector Voltage versus Spectral Irradiance, Chamber Test 2, Runs 1 to 4
(Not Corrected for V_D)

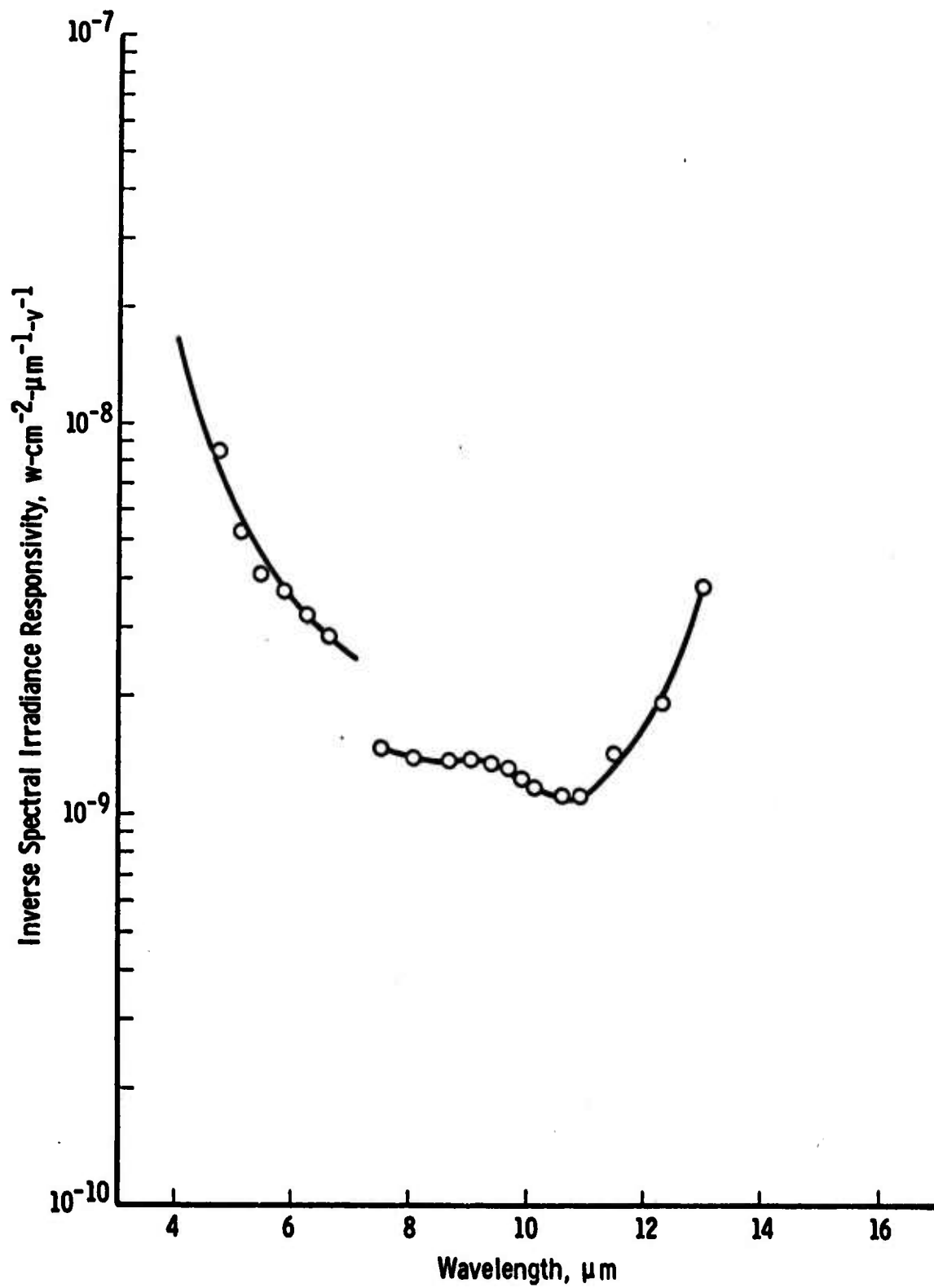


Fig. 14 Preliminary Inverse Spectral Responsivity versus Wavelength

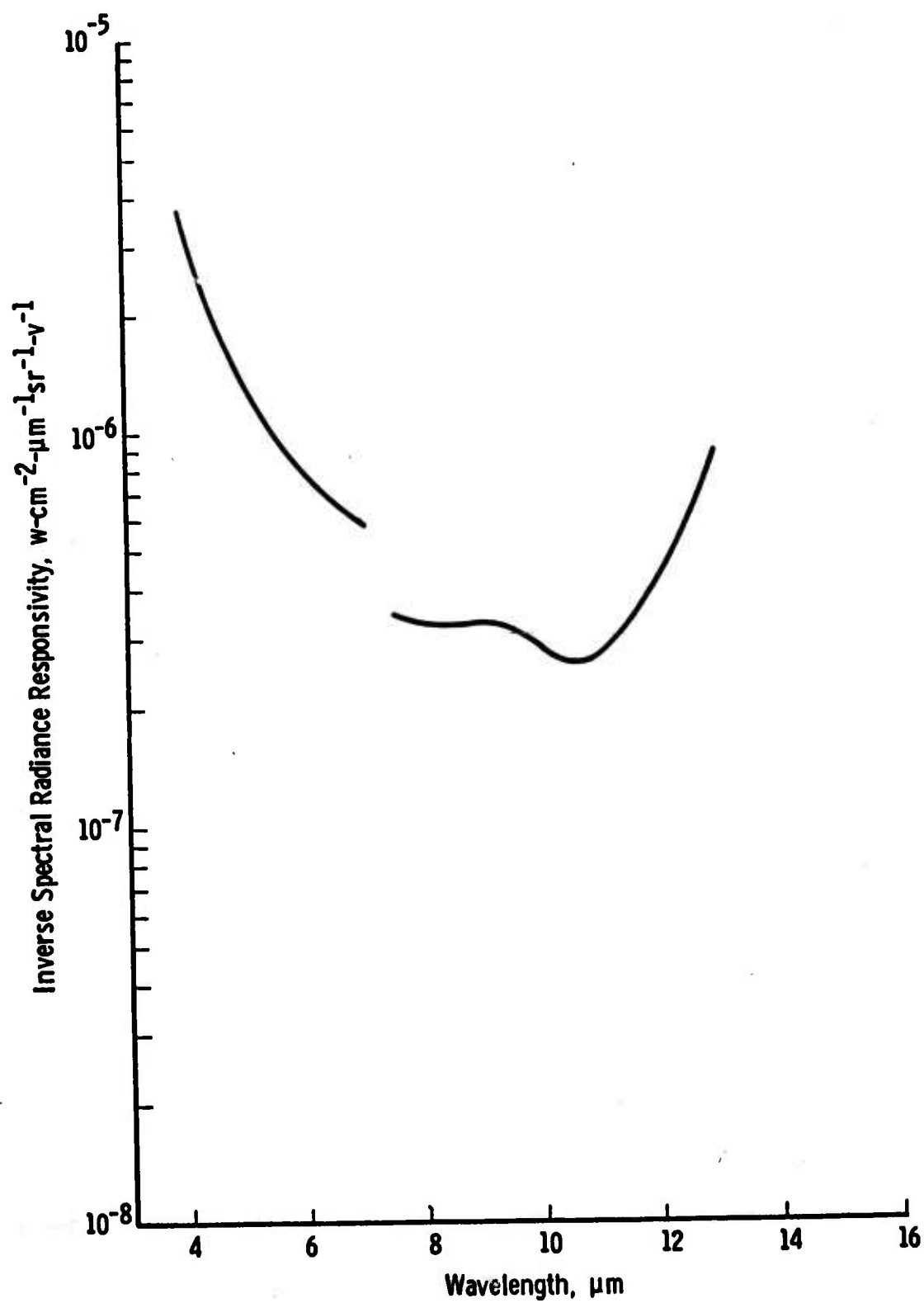


Fig. 15 Inverse Spectral Radiance Responsivity versus Wavelength

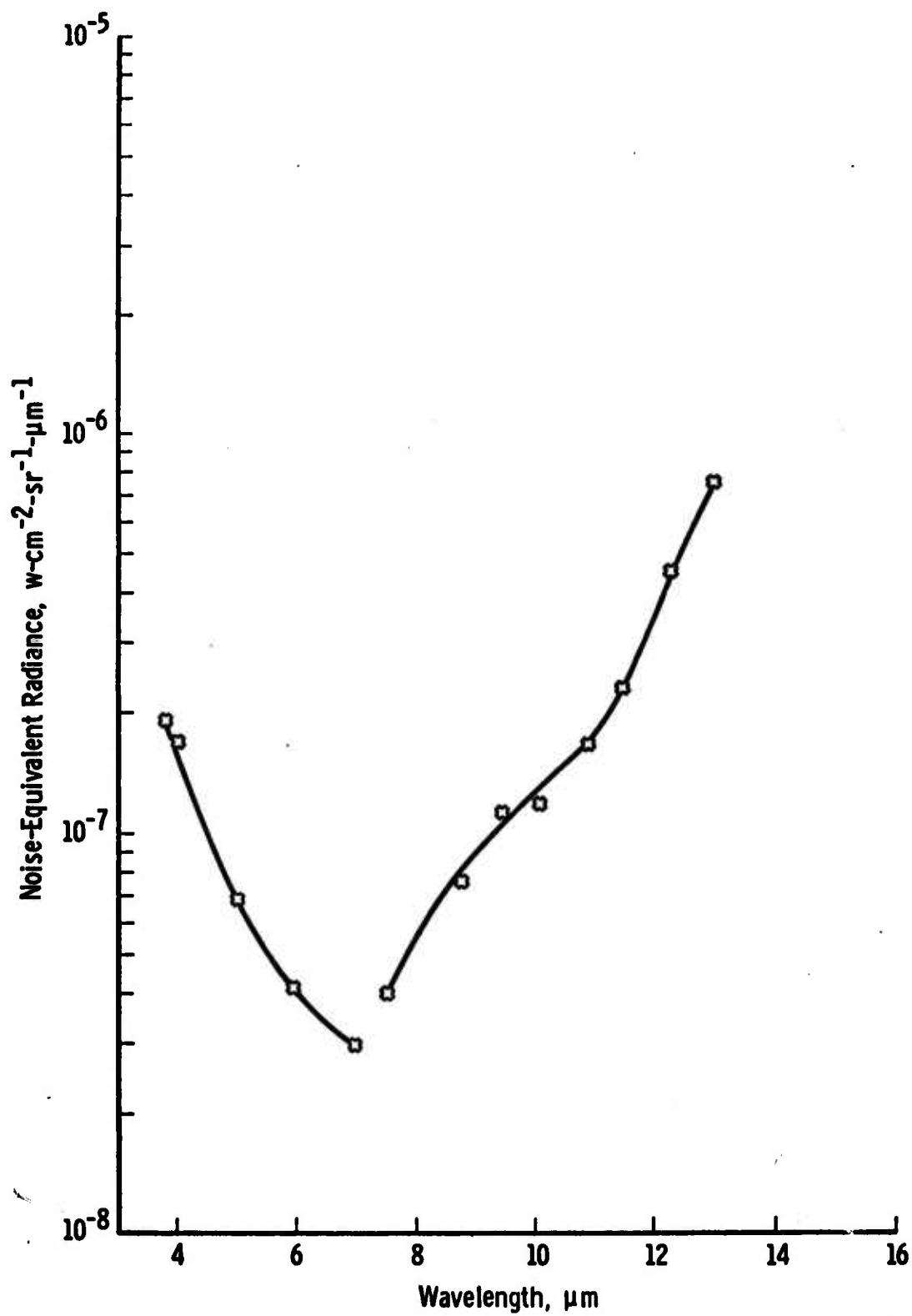


Fig. 16 Spectral Noise Equivalent Radiance

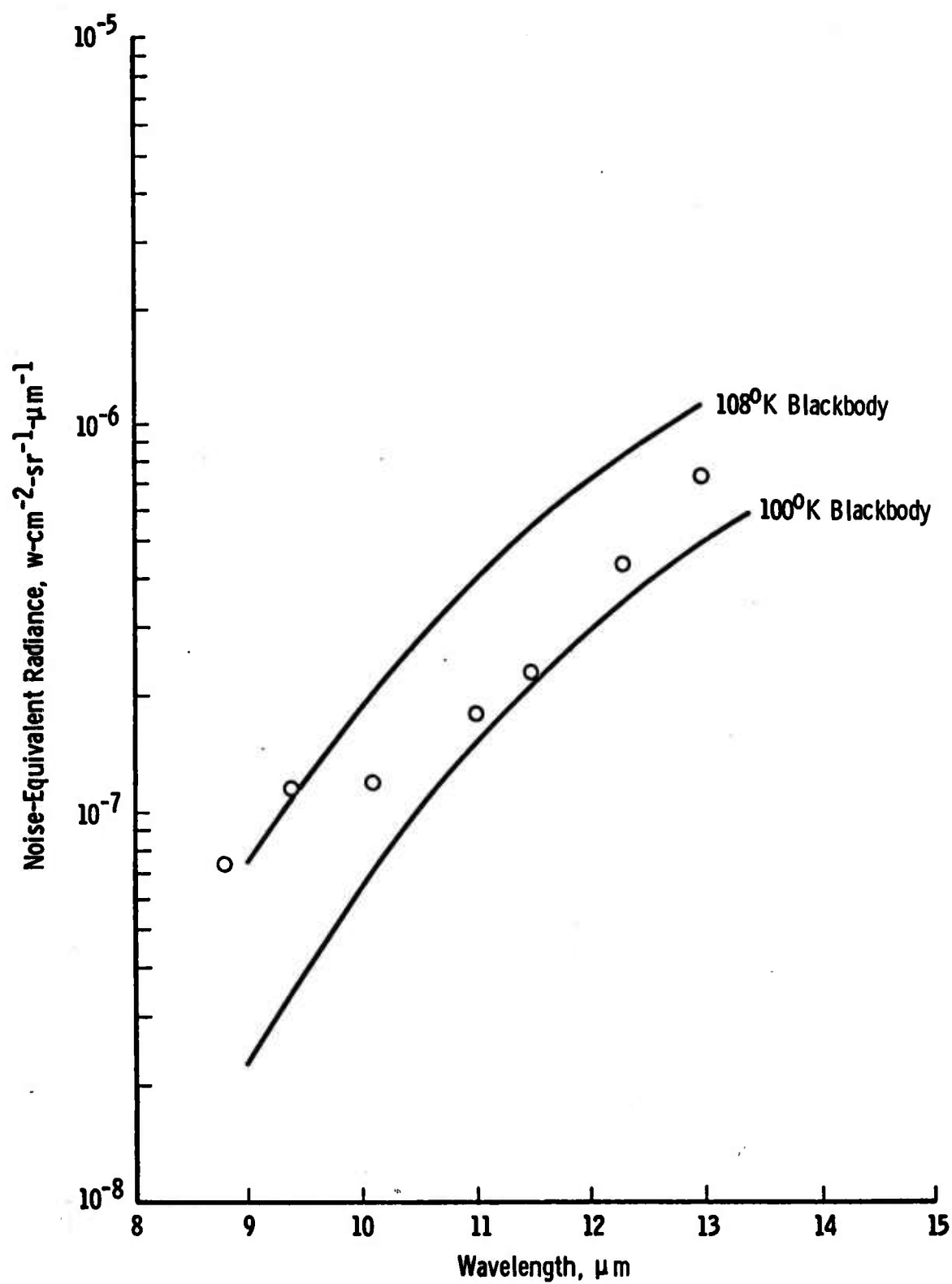


Fig. 17 Spectrometer Internally Generated Background Radiance

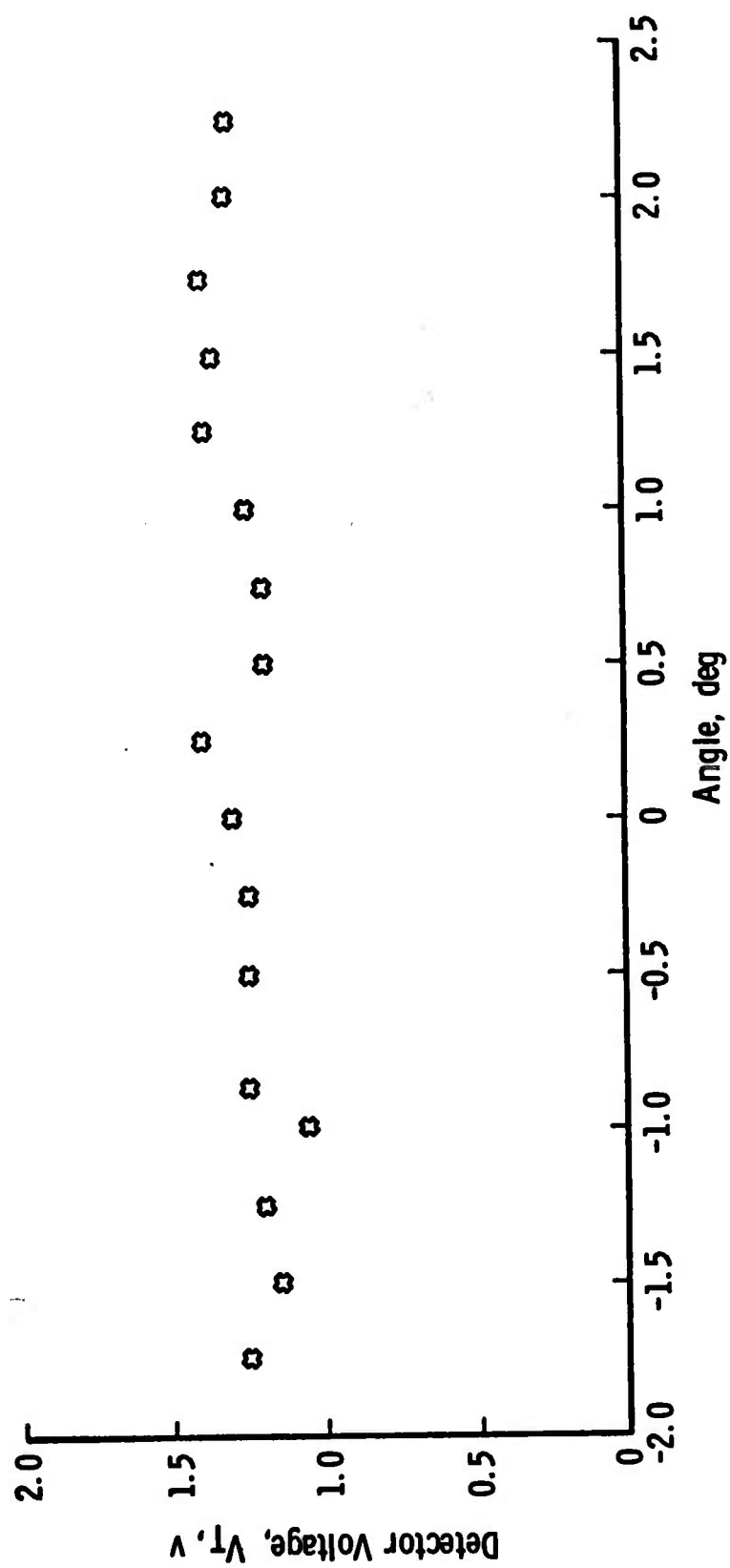


Fig. 18 Detector Voltage versus Angular Position of Blackbody Sources

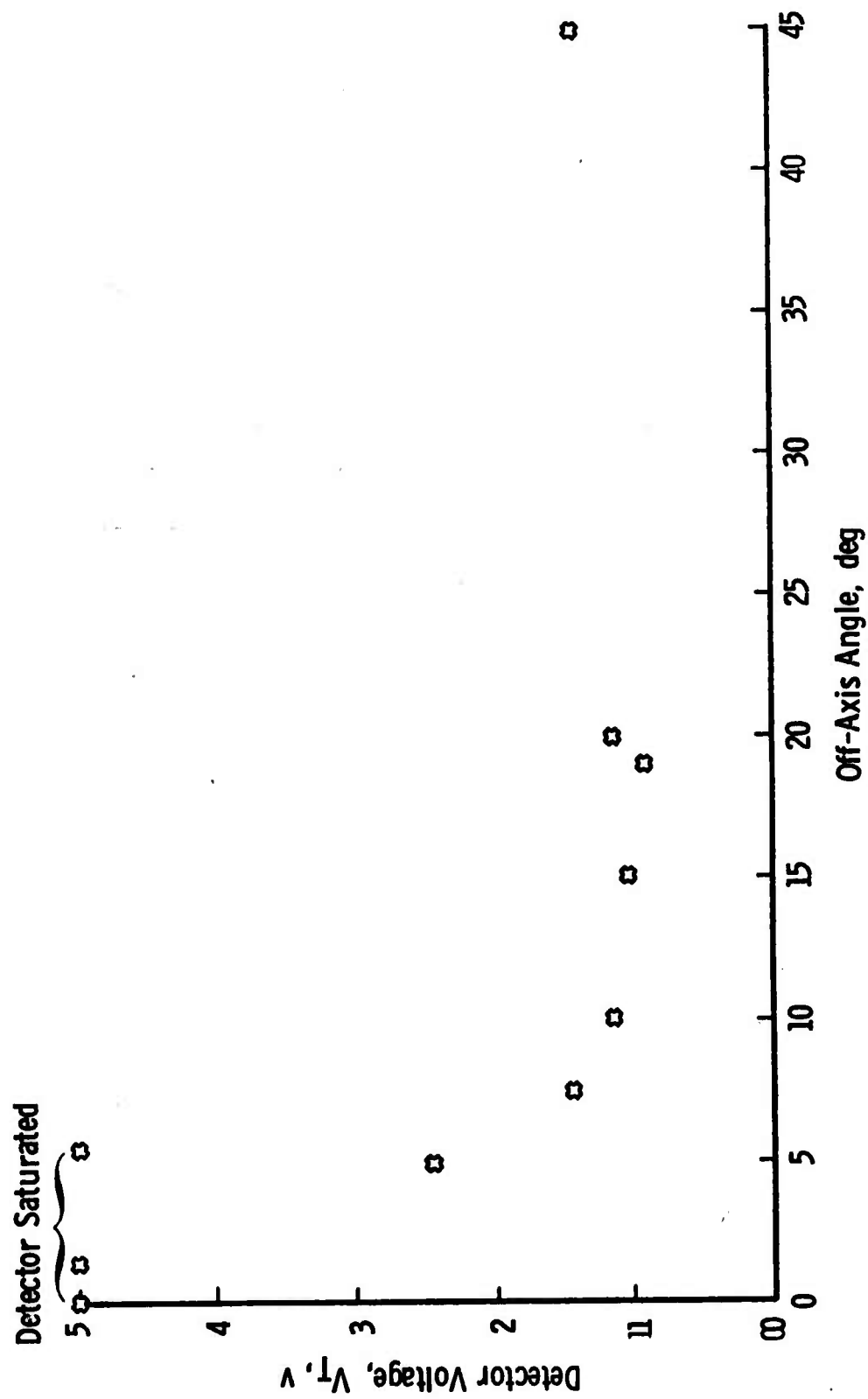


Fig. 19 Detector Voltage versus Angular Position of Earth Simulator Source

TABLE I
WAVELENGTH CALIBRATION OF AFCRL CVF SPECTROMETER

<u>Index No.</u>	<u>AFCRL October Calibration</u>	<u>AEDC Bench Test</u>
1	8.031	7.84
2	7.354	7.33
Wide Metal Strip (Zero Reset)		
3	7.331	7.80
4	6.840	6.71
5	6.588	6.51
6	6.099	6.00
7	5.830	5.72
8	5.318	5.22
9	5.048	4.91
10	4.516	4.43
11	4.298	4.13
12	3.784	3.62
Narrow Metal Strip		
13	13.070	13.00
14	12.750	12.67
15	12.261	12.15
16	11.396	11.13
17	10.931	10.70
18	9.825	9.80
19	9.415	9.23
20	8.470	8.30

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Arnold Engineering Development Center ARO, Inc., Operating Contractor Arnold Air Force Station, Tennessee 37389		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	
		2b. GROUP N/A	
3. REPORT TITLE CALIBRATION OF A FIRST-GENERATION CIRCULAR VARIABLE FILTER SPECTROMETER.			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) January 13 to April 17, 1970 - Final Report. 13 Jan - 17 Apr 70.			
5. AUTHOR(S) (First name, middle initial, last name) R. M. Warner / ARO, Inc. 12/38 p.			
6. REPORT DATE August 1970 15		7a. TOTAL NO. OF PAGES 36	7b. NO. OF REFS 0
8a. CONTRACT OR GRANT NO. F40600-71-C-0002		8b. ORIGINATOR'S REPORT NUMBER(S) 14 AEDC-TR-70-152	
8c. PROJECT NO. 8692, ARO-SAP 43		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) ARO-VKF-TR-70-152	
10. DISTRIBUTION STATEMENT This document may be further distributed by any holder only with specific prior approval of Air Force Cambridge Research Laboratory (CROR), L. G. Hanscom Field, Bedford, Mass. 01730 and Arnold Engineering Development Center (AETS), Arnold Air Force Station, Tenn.			
11. SUPPLEMENTARY NOTES 37389		12. SPONSORING MILITARY ACTIVITY Air Force Cambridge Research Laboratory (CROR), L. G. Hanscom Field, Bedford, Massachusetts 01730	
13. ABSTRACT To permit accurate evaluation of previous airborne measurements, the AFCRL first-generation circular variable filter (CVF) spectrometer was calibrated in the Aerospace Research Chamber (7V). Testing consisted of calibration and linearity checks, angular response measurements, off-axis rejection measurements, and modulation transfer function determination. The calibration measurements defined the spectral radiance responsivity over a 4.0- to 13.0-micron wavelength range and the noise-equivalent radiance (NER) of the instrument. This document may be further distributed by any holder only with specific prior approval of Air Force Cambridge Research Laboratory (CROR), L. G. Hanscom Field, Bedford, Massachusetts 01730 and Arnold Engineering Development Center (AETS), Arnold Air Force Station, Tennessee 37389.			

DD FORM 1473
1 NOV 65UNCLASSIFIED 04/2 550
Security Classification

UNCLASSIFIED

Security Classification

14

KEY WORDS

LINK A

LINK B

LINK C

ROLE

WT

[illegible]

WT

	NAME	ROLE
1	JOHN J. ...	...
2	JAMES E. ...	...
3	JOHN F. ...	...
4	JOHN G. ...	...
5	JOHN H. ...	...
6	JOHN I. ...	...
7	JOHN K. ...	...
8	JOHN L. ...	...
9	JOHN M. ...	...
10	JOHN N. ...	...
11	JOHN O. ...	...
12	JOHN P. ...	...
13	JOHN Q. ...	...
14	JOHN R. ...	...
15	JOHN S. ...	...
16	JOHN T. ...	...
17	JOHN U. ...	...
18	JOHN V. ...	...
19	JOHN W. ...	...
20	JOHN X. ...	...
21	JOHN Y. ...	...
22	JOHN Z. ...	...
23	JOHN A. ...	...
24	JOHN B. ...	...
25	JOHN C. ...	...
26	JOHN D. ...	...
27	JOHN E. ...	...
28	JOHN F. ...	...
29	JOHN G. ...	...
30	JOHN H. ...	...
31	JOHN I. ...	...
32	JOHN K. ...	...
33	JOHN L. ...	...
34	JOHN M. ...	...
35	JOHN N. ...	...
36	JOHN O. ...	...
37	JOHN P. ...	...
38	JOHN Q. ...	...
39	JOHN R. ...	...
40	JOHN S. ...	...
41	JOHN T. ...	...
42	JOHN U. ...	...
43	JOHN V. ...	...
44	JOHN W. ...	...
45	JOHN X. ...	...
46	JOHN Y. ...	...
47	JOHN Z. ...	...
48	JOHN A. ...	...
49	JOHN B. ...	...
50	JOHN C. ...	...
51	JOHN D. ...	...
52	JOHN E. ...	...
53	JOHN F. ...	...
54	JOHN G. ...	...
55	JOHN H. ...	...
56	JOHN I. ...	...
57	JOHN K. ...	...
58	JOHN L. ...	...
59	JOHN M. ...	...
60	JOHN N. ...	...
61	JOHN O. ...	...
62	JOHN P. ...	...
63	JOHN Q. ...	...
64	JOHN R. ...	...
65	JOHN S. ...	...
66	JOHN T. ...	...
67	JOHN U. ...	...
68	JOHN V. ...	...
69	JOHN W. ...	...
70	JOHN X. ...	...
71	JOHN Y. ...	...
72	JOHN Z. ...	...
73	JOHN A. ...	...
74	JOHN B. ...	...
75	JOHN C. ...	...
76	JOHN D. ...	...
77	JOHN E. ...	...
78	JOHN F. ...	...
79	JOHN G. ...	...
80	JOHN H. ...	...
81	JOHN I. ...	...
82	JOHN K. ...	...
83	JOHN L. ...	...
84	JOHN M. ...	...
85	JOHN N. ...	...
86	JOHN O. ...	...
87	JOHN P. ...	...
88	JOHN Q. ...	...
89	JOHN R. ...	...
90	JOHN S. ...	...
91	JOHN T. ...	...
92	JOHN U. ...	...
93	JOHN V. ...	...
94	JOHN W. ...	...
95	JOHN X. ...	...
96	JOHN Y. ...	...
97	JOHN Z. ...	...
98	JOHN A. ...	...
99	JOHN B. ...	...
100	JOHN C. ...	...

WT

spectrometers

Calibración

calibrating

space environment simulation

tests

2. Circular Variable Spectrometer

filter

UNCLASSIFIED

Security Classification